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Maritime transport chain choice by carriers, ports and shippers

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ABSTRACT

A maritime transport chain is a network over which carriers, ports and shippers are involved in the movement of cargo. This paper formally deduces that the port choice literature is included in the maritime transport chain choice literature. Specifically, it demonstrates that determinants of the port choice by shipping lines and shippers found in the literature and determinants of shipping line and shipper choice by ports are also determinants of maritime transport chain choice. Further, a maritime transport chain is formalized as an equilibrium model. Existence and uniqueness results for the proposed maritime transport chain model are derived.

1. Introduction

Rather than port users (carriers and shippers) choosing a maritime supply chain, the literature has focused on port users choosing a port. Port users, however, may not choose a port but rather "a port-oriented supply chain in which the port is embedded as a critical element" (Magala and Sammons, 2008, p. 15).[2] Ports are part of a value-driven chain system competing with other value-driven chain systems (Robinson, 2002).[3] Recognition that ports are integrated in supply chains is found in Bichou and Gray (2004) and Marlow and Paixao (2003). The selection of port-oriented supply chains by port users is discussed in Bichou and Gray (2004), Carbone and De Martino (2003), Heaver (2002), Panayides, (2006), Paixao and Marlow (2003), Robinson (2002, 2006), and Wang and Cullinane (2006).

Lam (2011) has analyzed the activities of ports (as nodes) and shipping line routes (as links) in maritime supply chains by using the slot (the cargo-carrying) capacity of vessels deployed by container shipping lines in maritime supply chains. The analysis reveals that ports can have complementary relationships when they are connected by trade routes and serve the same supply chain.

Port choice by a cargo's journey from origin to destination has been investigated by Tran (2011), where the selection of a port is based upon the minimization of the overall cost of the cargo's journey. The overall cost of the cargo's journey includes ship cost, port tariff, inland transportation cost and inventory cost.

Port choice from a network perspective has been investigated by Tang et al., (2011) with respect to the impact of port connectivity (or inter-port relationships) on a port's overall attractiveness. The empirical results reveal that port efficiency is the most important factor for increasing the attractiveness of ports.

This paper develops a maritime transport chain choice model, where carriers seek to maximize chain profits, ports seek to maximize throughput and shippers seek to minimize chain logistics costs in choosing a maritime transport chain. A maritime transport chain is defined as a network over which carriers, ports and shippers are involved in the movement of cargo (a more formal definition is given in Definition 1 in Section 4). The choice of a maritime transport chain by carriers, ports and shippers is considered to be jointly rather than independently determined. Using the theory of variational inequalities, sufficient conditions for the existence and uniqueness of a maritime transport chain are then formally presented. (Note that Nagurney et al. (2002), presented a related model for general supply chains where manufacturers, retailers and consumers interact to determine equilibrium prices and quantities. On the other hand, the current model is specifically tailored to maritime transport chains, with fundamentally different behavioral assumptions.) The paper also formally deduces in a series of propositions that determinants of port choice by shipping lines and shippers found in the literature and determinants of shipping line and shipper choice by ports are also determinants of maritime transport chain choice (Sections

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[2] "The choice of a port is a by-product of a choice of a logistics pathway in which the total logistics cost is a major supply chain consideration" (Magala and Sammons, 2008, p. 16). For a discussion of port efficiency, see Wang et al. (2005) and Yan et al. (2009).

[3] A discussion of maritime networks for specific shipping lines is found in Fremont (2010).

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2 and 3). It is to be emphasized that the results presented in Sections 2 and 3 are very general results regarding maritime transport chains. Results in Sections 4 and 5, on the other hand, are particular to the proposed mathematical model.

In the following section, it is deduced via propositions that determinants of port choice by shipping lines and shippers found in the literature are also determinants of maritime transport chain choice by shipping lines and shippers, respectively. In Section 3, it is deduced via propositions that determinants of shipping line and shipper choice by ports are also determinants of maritime transport chain choice by ports. We then proceed (in Section 4) to develop a mathematical model for a maritime transport chain, where the choice of a maritime chain is made by carriers, shippers and ports acting in a non-cooperative fashion. Section 5 contains existence and uniqueness results for the maritime transport chain model as defined in Section 4. Finally, conclusions are presented in Section 6.

2. Determinants of port choice by shipping lines and shippers

Does the shipping line or the shipper choose a port? There is no consensus answer to this question. This may be due to the fact that the port choice literature has investigated port choice by the shipping line and the shipper independently of each other.[4]

2.1. Determinants of port choice by shipping lines

Determinants of port choice by shipping lines found in the literature include: (1) port location (Chang et al., 2008), (2) ocean distance between the origin port and the foreign port (Malchow and Kanafani, 2001), (3) port berth availability (Chang et al., 2008), (4) port cargo (import, export and transshipment) volume (Chang et al., 2008), (5) port prices (Tongzon and Sawant, 2007), (6) range of port services (Tongzon and Sawant, 2007), (7) port efficiency (Chow, 2007; Tang et al., 2011), (8) port physical and technical infrastructure (Lirn et al., 2003), (9) availability of port hinterland transport connections (Wiegmans et al., 2008) and, (10) inland distance between origin locations and origin ports for exports (Malchow and Kanafani, 2001).

Proposition 1. Determinants of port choice by shipping lines are also determinants of maritime transport chain choice by shipping lines.

Proof. Under the reasonable assumption that maritime transport chain choice by a shipping line is a function of its maritime transport chain profit and that this profit is a function of the determinants of port choice by the shipping line, it then follows that maritime transport chain choice by a shipping line is a function of the determinants of port choice by a shipping line. **Q.E.D.**

Note that the determinants of shipping line port choice discussed above are expected to have a positive effect on a shipping line's profit. For example, the greater the port cargo volume of a maritime transport chain, the greater the likelihood that the shipping line can increase its profit, all else held constant. If a port can turnaround ships faster (port efficiency), i.e., a ship's time in port will be less, a shipping line's ships will incur less cost in port and thus increase its profit in servicing the maritime transport chain, all else held constant. Finally, we want to emphasize that in Proposition 1 we are simply deducing that *one specific* set of determinants for a maritime transport chain choice by shipping lines is given by the determinants of port choice (by shipping lines). In other words, there might be *other* determinants. This same remark also applies to Propositions 2–4 below.

2.2. Determinants of port choice by shippers

Determinants of port choice by shippers found in the literature include: (1) distance between exporter or importer location and port location (Tiwari et al., 2003), (2) port prices (Ng, 2006), (3) port frequency of ship calls (Ugboma et al., 2006), (4) port frequency of cargo loss and damage (Murphy et al., 1991), (5) service quality (Ng, 2006), (6) port efficiency (Ugboma et al., 2006), (7) port equipment availability (Murphy et al., 1991), (8) port information services (Murphy et al., 1992) and (9) size of the shipper (Steven and Corsi, 2012).

Proposition 2. Determinants of port choice by shippers are also determinants of maritime transport chain choice by shippers.

Proof. Under the reasonable assumption that maritime transport chain choice by a shipper is a function of its maritime transport chain logistics costs and that these logistics costs are a function of the determinants of port choice by the shipper, it then follows that maritime transport chain choice by a shipper is a function of the determinants of port choice by the shipper. **Q.E.D.**

Note that the determinants of port choice by a shipper discussed above are expected to affect a shipper's logistics cost. For example, less the distance between a shipper's location and a port's location in a maritime transport chain, less will be the logistics costs of the shipper's cargoes in moving over the chain than over a chain for which the distance is greater, all else held constant. Also, a port with more frequent ship calls will result in lower inventory costs for shippers' cargoes, since the cargoes on average will be waiting less time in port to board a ship and therefore will reach their destinations sooner, all else held constant.

3. Determinants of shipping line and shipper choice by ports

The literature has investigated determinants of port choice by shipping lines and shippers, but not the alternative—i.e., determinants of shipping line and shipper choice by ports. It is well known that ports seek to increase their cargo throughput by attracting ships of shipping lines and cargoes of shippers to their ports.

3.1. Determinants of shipping line choice by ports: anecdotal evidence

A port can affect the number of ship calls by a shipping line by entering into long-term contracts with shipping lines for their ships to call at the port and delivery a minimum amount of cargo per time period of the contract. In return, the shipping lines would be subjected to lower port charges and/or other benefits. A port long-term shipping-line contract is a means by which a port can increase its ship calls and thus a determinant of shipping line choice by ports. Virginia International Terminals (VIT), a non-profit company that operates the Port of Virginia's marine terminals (USA), has entered into ten-year contracts with a number of shipping lines to call the port and provide a minimum number of containers per time period.

In response to the wishes of shipping lines to utilize larger ships (because of economies of ship size at sea) and the wishes of ports to increase port throughput, ports are under increasing pressure to dredge their channels deeper to accommodate larger-sized ships. Thus, the dredging of port channels to deeper depths can be used by

[4] The study by Tiwari et al. (2003) simultaneously models a shipper's port and carrier choice.